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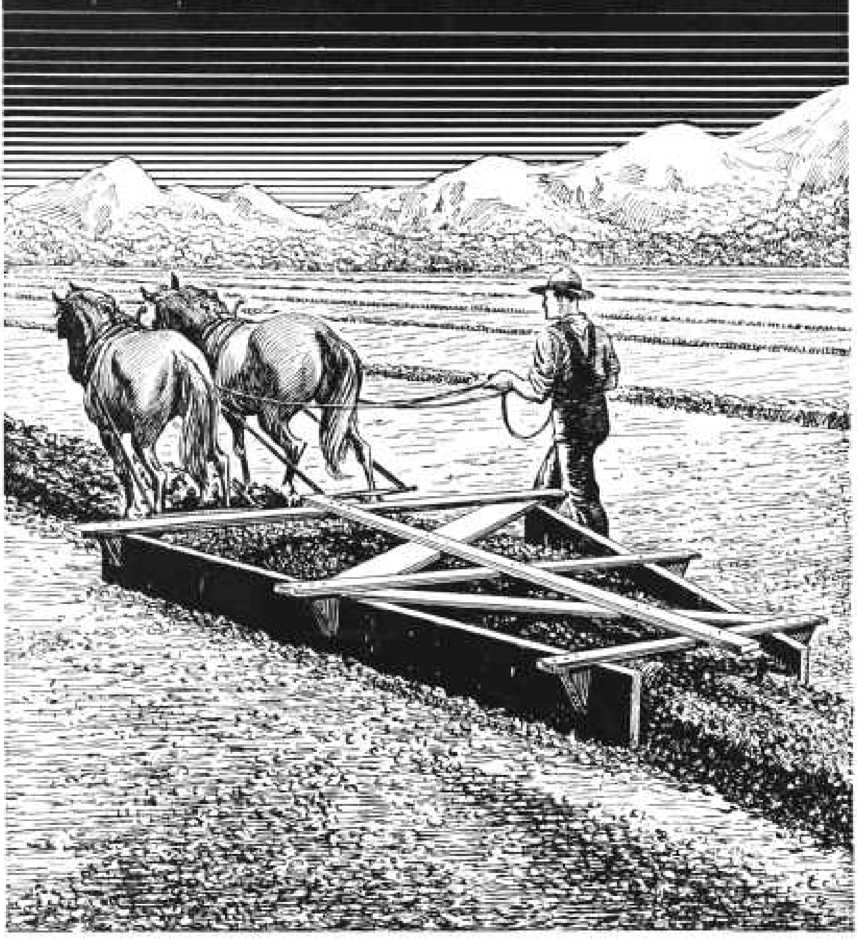
The BORDER METHOD of IRRIGATION



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THE PRIMARY PURPOSE of irrigation is to maintain enough moisture in the soil around the roots of plants, and this can be done only by an efficient method. Crop yields in irrigation farming depend for the most part on uniform distribution of the proper quantity of water at the right time. The border method described in this bulletin, one of several methods used in Western States, is well adapted to many soils and crops.

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THE BORDER METHOD OF IRRIGATION

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THE BORDER METHOD of irrigation consists essentially in the division of the field into a series of strips by low, flat levees extending in the direction of the slope. Water is turned into the upper end of each strip and moves down the slope in a thin sheet.

CHOICE OF METHOD

About a dozen methods of applying irrigation water have come into use in the United States. This diversity resulted from the variety of conditions and requirements found not only in widely separated localities but also on farms of the same locality. In selecting a method it is necessary to consider seasonal rainfall, slope and general character of the ground surface, water supply and how it is delivered, kinds of crops to be grown and rotation, and the ability of the soil and subsoil to take water. There are also questions as to cost and permanency of the work.

Sometimes only a single method will meet all requirements. In the irrigation of rice in the Gulf States the contour check method with its modifications is standard. In western practice such crops as potatoes, sugar beets, and corn, are planted in rows and cultivated, and for such crops the furrow method is best. As a rule, however, the farmer may choose among several ways, and it is not always easy to make the best choice. Some farmers do not know enough about various methods to make a selection and, therefore, merely imitate their neighbors. So common is this practice that frequently large areas made up of farms differing widely in physical condition are irrigated throughout by the same method.

FACTORS FAVORING THE BORDER METHOD

A smooth, regular surface having a slope in one direction of about 2.5 inches in 100 feet is ideal for the border method. It is possible to make borders on slopes 1 inch or less and on steeper slopes up to

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2 feet and more in 100 feet. Borders have been used on slopes as great as 7½ feet in 100 feet, but on such land there is great danger of soil and crop erosion.

The quantity of water which can be turned in depends on the size of each strip, its slope, and other conditions. On heavy soil and on narrow, short strips the head may be cut to half a cubic foot per second, and on wide strips and permeable soil 10 cubic feet per second may be none too much. A large volume of water cannot be handled successfully on steep slopes, but it is always possible to divide a head between two or more strips.

The kind of crop to be grown must usually be considered along with rotation of crops. It seldom pays to prepare a field for the border method for a single crop. Since this method is well adapted to alfalfa, clover, and other forage crops, and also to small grain, the forage crops may be rotated with the grains without modifying the method. Where row crops, such as potatoes, sugar beets, corn, or cotton are included in the rotation with forage or small grain the border method may be used for the forage or grain and, with a little reworking of the land, the furrow method may be used for the row crops. Sometimes, as, for instance, where the soil crusts after being flooded or the slope is too steep, it is hard to start crops with the border method. In many such cases the corrugation method may be used to start the crops, and the border method may be used thereafter. This combination is especially useful with perennial forage crops such as alfalfa and grass pastures.

The border method may be used on any type of soil suitable for irrigation. It is the best method for very permeable soils when other conditions are favorable. On slightly permeable soils the method must be modified by putting small cross dikes at intervals down the strips.

The cost of preparing land for the border method is low as compared with the cost of installing most other systems. Besides, it is usually feasible to get a fair crop at small cost by the use of temporary borders, putting off the making of permanent borders until after harvest when it may be done without undoing much of the previous season's work.

PREPARING THE LAND AND DITCHES

The first step in preparing a farm for irrigation is a study of the physical conditions. This study should include a survey of the land; an estimate of the water supply, including place, time, and quantity of delivery; and tests of the depth and permeability of the soil. The information obtained is used to fix the location, design, and capacity of the field and waste ditches, border structures, and strips. Finally the ditches must be dug or the pipes laid, the structures built, and the border strips prepared.

SURVEYS

The subdivision of large units of land, such as townships, into square units containing 640 or 160 acres possesses advantages over irregular surveys. On the other hand, a rigid adherence to rectangular tracts on an irrigation project frequently places a handicap on the undertaking at the beginning which no future changes can lift. The reason is that water supply is of first importance to an irrigated farm, and the shape and boundaries should conform to the water channels as well as to the lay of the land, soil types, and other factors.

The State Land Settlement Board of California adopted with satisfactory results the logical plan of subdividing land for State colonies in conformity with the topography. Figure 1 is a sketch of farm lot no. 74 of the Durham colony showing 6-inch contours and two natural ravines. Figure 2 shows the same lot and indicates the size and the direction of the borders and of the supply and waste ditches.

In laying out farm systems for any method of irrigation, contour surveys should first be made, especially if the surface is at all uneven or irregular. Such contours can be readily located and mapped by

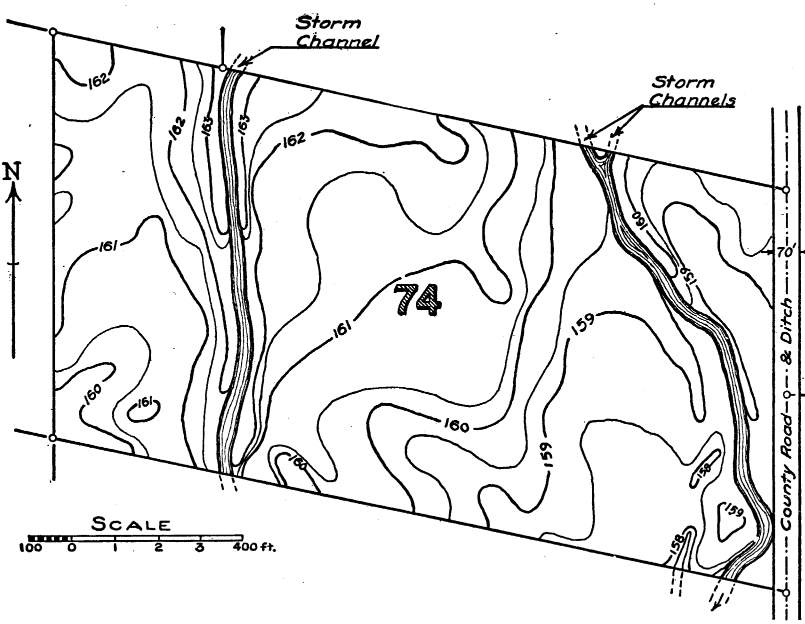

FIGURE 1.—Farm lot no. 74 of the Durham colony, showing contours.

dividing the field into 100-foot squares and taking an elevation at each of the corners. The benefits of contour surveys as a rule amply justify their cost.

The map of the farm should show contours; location of streams, ditches, pipe lines, or wells supplying water; drainage channels; roads; building sites; etc. The location of the field laterals, structures, and border strips can be worked out on this map. After satisfactory locations for these features have been found on the map they are staked out in the field. The principal advantage of a complete contour map is that many different locations of ditches and border strips can be tried out on the map without spending extra time and work staking them out. The final result will probably be a better system.

Even with the aid of a good map it is sometimes impossible to be sure, in advance of actual trial, that the best combination has been found. For this reason it may be best to make a minimum of permanent improvements before the first irrigation season. Temporary ditches and earth or canvas dams may be used the first year, and in the light of the experience thus gained the permanent structures may be located and built.

SUPPLY DITCHES AND PIPES

The location of the ditches or pipes which supply water to the strips is fixed by the survey. Their capacity is governed principally by the quantity of water that can be obtained from the canal system or pumping plant.

Canal companies and other irrigation agencies differ widely in ways of delivering water. Quantities delivered vary from less than 1 cubic foot per second to more than 10 cubic feet per second and times of delivery from a continuous stream to rotation periods of 45-day intervals. Since the conditions which govern the delivery of water from a

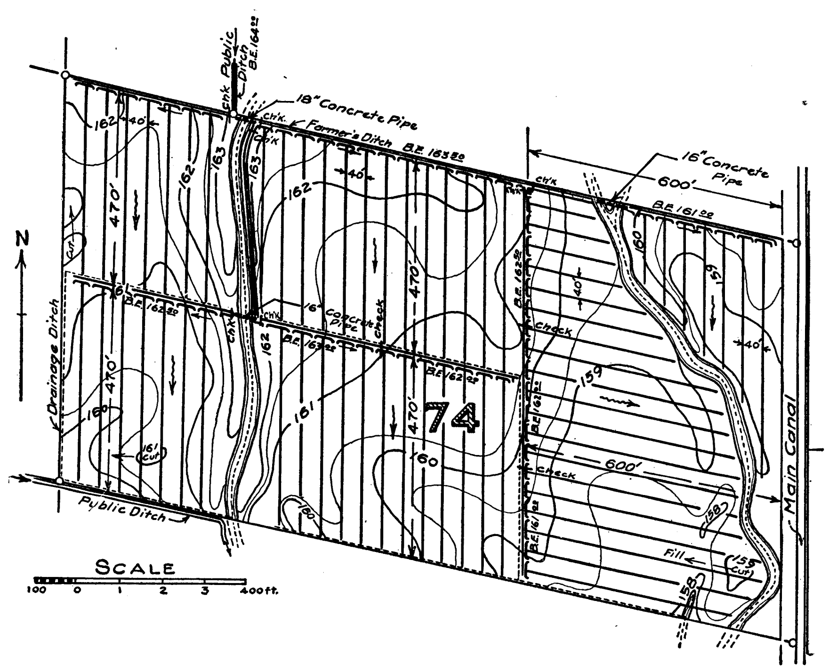

FIGURE 2.—Farm lot no. 74, showing the size and direction of the borders and of the supply ditches and draws.

large system can seldom be modified by the water user, the irrigator under such a system is obliged to adapt the capacity of his supply ditches and borders to the quantity of water that can be obtained from the canal system at any one time. The farmer having an individual right from a natural stream must build his system to handle the water to which he is entitled. The man using a pumping plant can often adjust the size of his plant to conform to the needs of his system. The size of stream best adapted to the border method is discussed more fully in the section on the preparation of strips (p. 12).

Cross sections of five supply ditches are shown in figure 3.

The form of these is fixed somewhat arbitrarily, since it depends upon the kind of implement used in construction. Table 1 gives the mean velocity and carrying capacity of each of these ditches when running full, as indicated in figure 3, on several different grades.

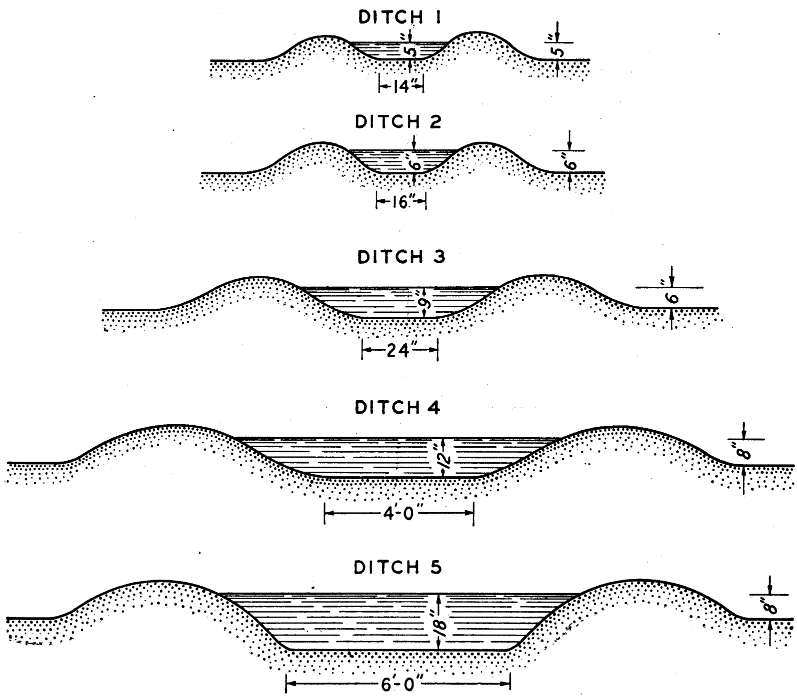

FIGURE 3.—Cross sections of typical supply ditches.

TABLE 1.—*Mean velocity and discharge in ditches with different grades*

FARM DITCH No. 1

Grade			Mean velocity per second	Discharge		
					Miner's inches	
Per rod	Per 100 feet	Per mile		Per second	40 equal 1 second-foot	50 equal 1 second-foot
Inches	*Feet*	*Feet*	*Feet*	*Cubic feet*		
½	0.25	13.33	1.0	0.7	25	35
1	.51	26.67	1.4	1.0	40	50
1½	.76	40.00	1.8	1.2	45	60
2	1.01	53.33	2.1	1.4	55	70
2½	1.26	66.67	2.3	1.5	60	75
3½	1.77	93.33	2.7	1.8	70	90

FARM DITCH No. 2

¼	0.13	6.67	0.9	0.9	35	45
½	.25	13.33	1.2	1.2	50	60
1	.51	26.67	1.8	1.8	70	90
1½	.76	40.00	2.2	2.2	90	110
2	1.01	53.33	2.5	2.5	100	130
2½	1.26	66.67	2.8	2.8	110	140

TABLE 1.—*Mean velocity and discharge in ditches with different grades*—Continued

FARM DITCH No. 3

Grade			Mean velocity per second	Discharge		
					Miner's inches	
Per rod	Per 100 feet	Per mile		Per second	40 equal 1 second-foot	50 equal 1 second-foot
Inches	*Feet*	*Feet*	*Feet*	*Cubic feet*		
⅛	0.06	3.33	0.8	1.9	75	95
¼	.13	6.67	1.2	2.8	110	140
½	.25	13.33	1.7	3.9	160	190
¾	.38	20.00	2.1	5.0	200	250
1	.51	26.67	2.4	5.5	220	280
1¼	.63	33.33	2.7	6.2	250	310

FARM DITCH No. 4

1/16	0.03	1.67	0.7	3.7	150	180
⅛	.06	3.33	1.1	5.3	210	260
¼	.13	6.67	1.6	7.9	310	390
⅜	.19	10.00	1.9	9.5	380	480
½	.25	13.33	2.2	11	440	550
¾	.38	20.00	2.7	14	540	680

FARM DITCH No. 5

1/16	0.03	1.67	1.0	11	460	570
⅛	.06	3.33	1.4	16	650	810
3/16	.09	5.00	1.8	20	800	1,000
¼	.13	6.67	2.1	24	960	1,200
⅜	.19	10.00	2.6	29	1,200	1,500
7/16	.22	11.67	2.8	31	1,300	1,600

Farm ditches built in permeable soils are wasteful because of the large percentage of the flow which percolates through the bottom and sides and is lost. To prevent this loss and otherwise improve the methods of distributing and controlling water, pipes often are used in place of earthen ditches. Where water is pumped, pipes must generally be used to convey the water from the pump to the highest point of the land to be irrigated. The kinds of pipe most commonly used are concrete and machine-banded wood stave. Unless the latter is made of redwood or is creosoted or otherwise treated, it is subject to rapid decay. The fact that farm irrigation systems generally are alternately wet and dry tends to shorten the life of wood pipe and of other timber structures.

Table 2 gives the capacity of four sizes of concrete pipe when flowing full on various grades. Wood or steel pipe will carry somewhat more water on the same grades. Pipes ordinarily are not laid on a uniform grade like open ditches but below that line. The grade or fall shown in the first part of table 2 is the total fall in a pipe in a gravity system or of the water pressure in a pump discharge line divided by the length of the pipe.

TABLE 2.—*Mean velocity and discharge of concrete pipe flowing full*[1]

PIPE 6 INCHES IN DIAMETER

Grade			Mean velocity per second	Discharge		
					Miner's inches	
Per rod	Per 100 feet	Per mile		Per second	40 equal 1 second-foot	150 equal 1 second-foot
Inches	*Feet*	*Feet*	*Feet*	*Cubic feet*		
3/16	0.11	5.8	1.0	0.2	8	10
15/16	.46	24.0	2.0	.4	16	20
21/16	1.04	55 0	3.1	.6	24	30
511/16	2.88	152.0	5.1	1.0	40	50
111/16	5.60	296.0	7.1	1.4	56	70
PIPE 8 INCHES IN DIAMETER						
1/8	0.06	3.2	0.9	0.3	12	15
5/8	.32	17.0	2.0	.7	28	35
1¼	.64	34.0	2.9	1.0	40	50
5	2.54	134.0	5.7	2.0	80	100
11⅜	5.73	303.0	8.6	3.0	120	150
PIPE 12 INCHES IN DIAMETER						
1/8	0.07	3.7	1.1	0.6	24	30
3/8	.20	11.0	1.8	1.0	40	50
19/16	.80	42.0	3.7	2.0	80	100
6¼	3.15	166.0	7.3	4.0	160	200
PIPE 18 INCHES IN DIAMETER						
7/16	0.22	12.0	2.8	5.0	200	250
7/8	.44	23.0	4.0	7.0	280	350
113/16	.90	48.0	5.7	10.0	400	500
4	2.03	107.0	8.5	15.0	600	750

[1] Adapted from table 6, Dept. Bull. 852, U. S. Department of Agriculture.

STRUCTURES

The most common structures in border irrigation are the border gates controlling the water entering the strips. These are made of lumber or concrete or a combination of the two. Metal head gates inserted in pipes are also used. As in the case of supply or head ditches, the capacity of the gates varies from 1 to more than 10 cubic feet per second, and it is customary to design each of such a size that it can transmit the entire flow of the head ditch or pipe. Figure 4 shows a standard single-wing gate of wood which may be built in two different sizes, one of 1 to 3 cubic feet per second capacity, and one of 3 to 5 cubic feet per second capacity, the details of which are given in table 3. This gate is often built of 1¼-inch cedar lumber but may well be built of 2-inch material. Figure 5 shows a set of larger gates of the double-wing type, ranging in capacity from 3 to more than 10 cubic feet per second. The latter are used for the larger heads and in light permeable soils subject to erosion. The dimensions are given in table 4.

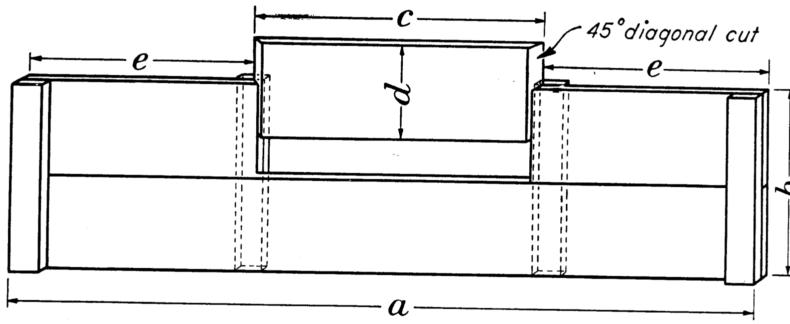

FIGURE 4.—Standard single-wing wooden border gate.

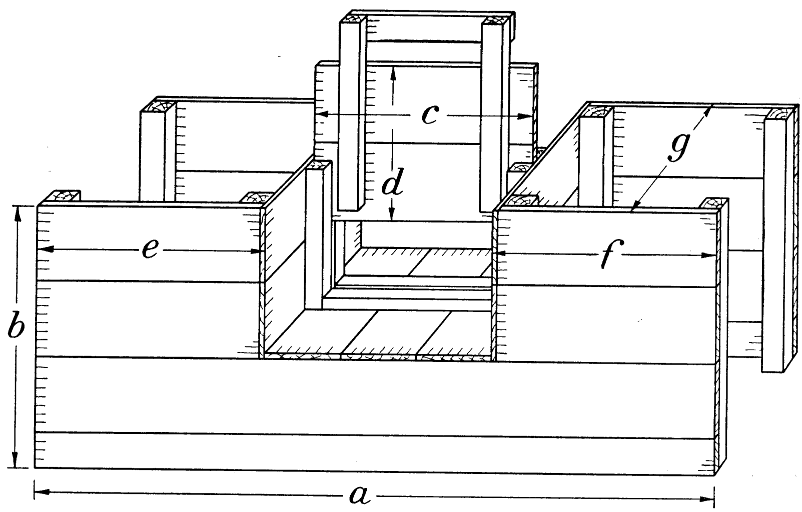

FIGURE 5.—Standard double-wing border gate.

TABLE 3.—*Dimensions of border gate shown in figure 4*

Designed for heads of— (Second-feet)	*a*	*b*	*c*	*d*	*e*
	Feet	*Feet*	*Feet*	*Feet*	*Feet*
1 to 3	8	2	3	1	2.5
3 to 5	10	2	4	1	3

TABLE 4.—*Dimensions of border gate shown in figure 5*

Designed for heads of— (Second-feet)	*a*	*b*	*c*	*d*	*e*	*f*	*g*
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
3 to 6	9	3.5	3	2	3	3	3
6 to 10	12	4	4	2	4	4	3.5
10 and up	14	4	5	2	4.5	4.5	4

Because of the short life of untreated lumber when in contact with earth, concrete border gates are being used on a number of canal systems. The design of lumber forms for one of this type is shown in figure 6.[1] The simplicity of this design and the ease with which it

[1] The author is indebted to S. H. Beckett, of the University of California, for the designs of border or head gates shown in figures 5 and 6.

can be installed make the cost little more than that of a wood gate. In addition to the cut-off wall under the gate, shown in figure 6, a

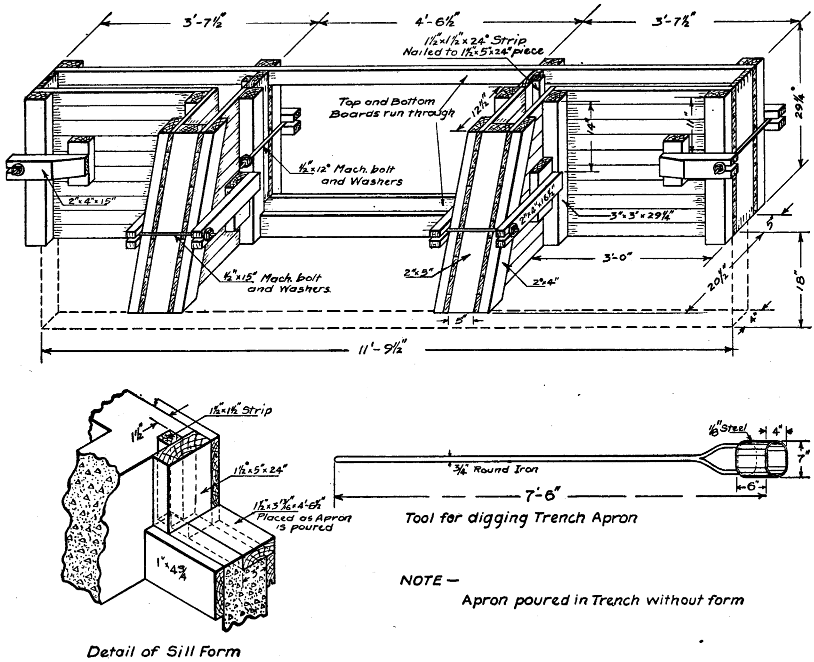

FIGURE 6.—Design of standard forms for concrete border gates.

concrete floor or apron is poured between the two side walls, extending back from the gate. Where streams of less than 8 cubic feet per second are used this gate may be made smaller.

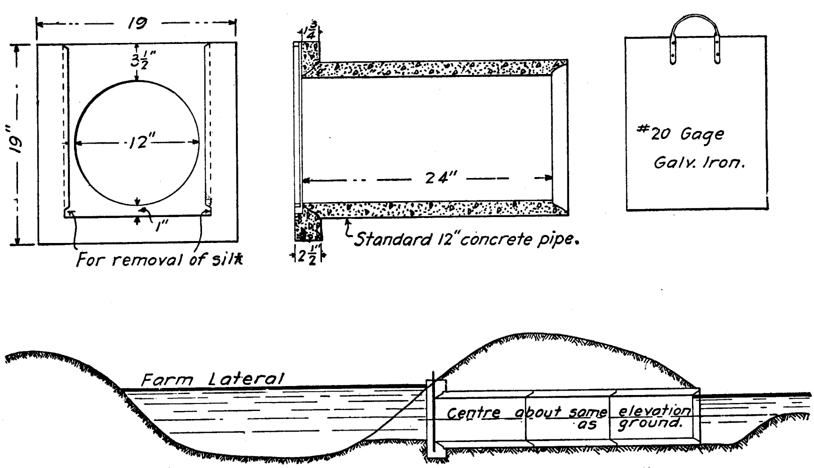

FIGURE 7.—Imperial Valley border gate.

Another type of concrete border structure with a metal gate is much used in the Imperial Valley of California. This type, shown in figure 7, consists of a joint of concrete pipe, usually 12 inches in

diameter, to which is precast a bulkhead of the same material. The gate proper is made of galvanized iron which fits into grooves in the bulkhead. At the bottom of each groove is an opening for the removal of sand and silt. The capacity of a 12-inch gate is about 3 cubic feet per second when laid so that the center of the pipe is on a level with the ground surface. One or two extra joints of pipe are used with each gate.

On the Umatilla project in Oregon satisfactory border gates and other structures are commonly made of concrete without the use of lumber forms. The banks are first put into proper shape, and the concrete, made of a rather dry mix, is then plastered over the surface to be covered. The gate grooves are formed by inserting the wooden gates in the green concrete before it has set. The gates should be thoroughly soaked beforehand or the wood will swell and crack the concrete. A check and a border gate made by this method are shown in figure 8.

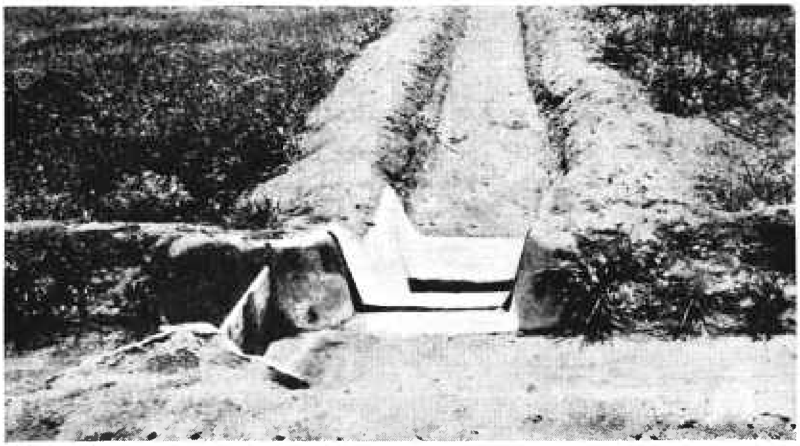

FIGURE 8.—Check and border gates made by plastering concrete on the soil, Umatilla project, Hermiston, Oreg.

If the strips to be irrigated are more than 25 or 30 feet wide two border gates should be used for each strip. Otherwise it may be impossible to make the water spread uniformly across the strips.

When a check in the head ditch is needed to permit the full head to enter the border gates, the canvas dam is about the cheapest and simplest device to use. The disagreeable labor of shifting the dams from place to place leads some farmers to use more permanent equipment. Checks of wood or of concrete with openings controlled by gates or flashboards are becoming more common. The double-wing border gate shown in figure 5 may be used for this purpose.

Where much silt is carried in the water, field ditches must be cleaned frequently. Under such conditions it is often best not to install gates as they interfere with machine cleaning.

In some cases the fall in the head ditch is so great that the bed of the ditch would be eroded if the flow of water were not checked. The concrete structure shown in figure 9 will serve both as a check to raise the water level when necessary to divert water to the strips and as a drop to take up some of the fall in the ditch.

When water is conveyed to border strips through pipes, it is distributed to the head of each strip through short stands resting on top of the feed pipe or on top of short branch lines. In case concrete pipe is used, the valve which controls the water is inserted in the top of the concrete stand, as indicated in figure 10. One valve may be used to feed several strips in turn by means of a portable hydrant, which is fastened to the stand, and the requisite number of joints of galvanized surface pipe. A section of a portable hydrant and the manner in which several strips may be watered from one valve are shown in figure 10.

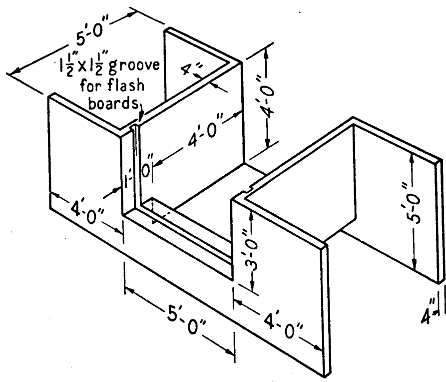

FIGURE 9.—Combined check and drop made of concrete.

Wooden flumes on trestles have been commonly used to continue supply ditches or other farm laterals across a stream, ravine, or other depression. Now, because of the high price of lumber and the likelihood of early decay of wood, semicircular galvanized-iron flumes on treated wood trestles are used. Concrete or metal pipe has lately been used extensively for this purpose.

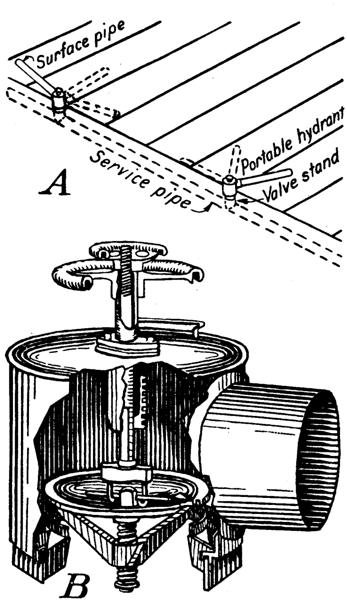

FIGURE 10.—*A*, Service pipe, surface pipe, and borders; *B*, valve and portable hydrant.

Concrete and metal pipes are also being used more frequently for culverts for road crossings. If the water flows through such a culvert on grade all that is necessary, apart from the pipe itself, is suitable protection at the inlet and outlet ends to keep the soil around the culvert from washing away. Embankments of earth or mixed earth and gravel, properly puddled and packed, or head walls of concrete encircling each end of the culvert will prevent such damage. If the bed of the ditch is higher than the roadway, concrete boxes are placed at the inlet and outlet ends of the culvert.

In other cases a road culvert may be combined with a check, drop, or division box, or two or more of these together, in which event the combined structure can be built more cheaply than several separate structures.

STRIPS

The two factors of greatest importance in the success or failure of a border irrigation system are (1) the balance between the size of the irrigation stream and the size and shape of the strips, and (2) the preparation of the strips for irrigation. A survey of the farm and a study of the soil are required to obtain the information necessary for laying out the border strips.

SOIL CHARACTERISTICS

The principal factors to consider in fixing the size and shape of the border strips are the water-holding capacity and the permeability of the soil. An ideal application of water would supply enough to moisten uniformly the entire root zone of the crop in all parts of the field and no more. Any given soil has a definite field water-holding capacity. If more water is supplied than is needed to bring the moisture content of the soil up to this capacity, either the soil will become waterlogged, or the excess water will be drained off. If the former happens, crop growth will be hindered, and if waterlogging becomes permanent the land may become unproductive. If much water percolates beyond reach of the roots the excess may accumulate under lower lands and ruin them by raising the water table. Moreover, directly or indirectly, irrigation water costs money, and in most areas irrigators can ill afford to waste it. Another harmful effect of deep percolation is the leaching away of plant food.

The capacity of soils to hold moisture in a form useful to crops will vary from about one-half inch to 2 inches depth of water for each foot depth of soil dried out by crop roots. Multiplying the useful capacity of the soil per foot by the depth of the root zone gives the quantity of water to apply at each irrigation. In general the coarser soils have the smaller water-holding capacity. Thus a sandy soil with a shallow-rooted crop might not require more than an inch of water at an application, whereas 8 or 10 inches might be economically applied to a deep-rooted crop on a clay loam soil.

The permeability of different soils varies even more than does the water-holding capacity. Tests of the rate of infiltration of water into soil indicate that when it is first applied to most dry soils it is taken up rather rapidly. With permeable soils the rate of infiltration does not decrease very much, whereas certain clays and clay adobes practically cease to take in water after the first foot or so has become saturated.

Unfortunately these two characteristics work in opposition in an irrigation system. The soils which should be irrigated heavily because of their high water-holding capacity take up water very slowly, while those on which light applications should be made, absorb water rapidly. Therefore water should be held on tight soils for a long time and on coarse soils only a very short time.

SIZE OF STREAM AND STRIPS

The size of the irrigation stream and the width of the strips should be so adjusted to each other that, by the time the sheet of water reaches the lower end, the whole strip is as well irrigated as possible. It is always inconvenient and sometimes impossible to collect the water flowing off the lower end of the strips and reuse it without waste.

With coarse soils the problem is to get the water over the border strips as rapidly as possible. To do this the strips are made narrow and short, and large streams of water are used. There is a limit to the size of stream that can be handled without danger of serious erosion, especially on newly planted or steep land. That limit is about 5 cubic feet per second on strips 30 to 40 feet wide. On soil protected by a crop and on flat slopes as much as 10 cubic feet per second can be handled on borders 50 to 60 feet wide. On the coarsest soils streams of this size will be entirely absorbed by the time they cover strips 200 to 300 feet long. Under such conditions it will take about 20 minutes

to cover a strip 150 feet long, and in that time much more water will have gone into the soil at the upper end of the strips than will be retained in the root zone. Making the strips even shorter would save water. This saving would entail the expense of extra labor in preparing the land and in applying the water as well as more inconvenience in other farm operations.

At the other extreme are the tight soils. On these the stream should be small in order that the water may move down the strip slowly. The difficulty here is that unless the strips are almost exactly level from side to side a small stream will not cover the strip deeply enough to moisten the high spots. It is difficult to get the soil so level that a stream of 1 cubic foot per second can be made to flow uniformly over a strip more than 30 feet wide. Borders on heavy soil can be made a quarter of a mile long without danger of overirrigating the upper ends. Borders up to 60 feet wide can be used with streams of 2 or 3 cubic feet per second, but they are seldom as satisfactory as narrower strips.

On tight soils it is necessary to provide some means of taking care of water flowing off the lower ends of the strips. Often it is necessary to allow the water to flow for a time after it reaches the lower end of the strip in order that the soil there may be properly moistened. On flat slopes the water may be ponded at the lower end of the strip. On heavy soils some means must be provided for drawing off the excess water before the crop is scalded.

On intermediate soils streams of 1 to 6 cubic feet per second may be used on strips 20 to 40 feet wide and 300 to 800 feet long, the smaller heads being used on the narrower strips and on the less-permeable soils.

PREPARING THE STRIPS

The desirable size and shape of strips having been determined, the strips must be fitted to the land as shown on the contour map. Generally the strips will be rectangular and will run with the steepest slope, but adjustments can be made to fit the fields. If the slope of the land is too great, the strips may run diagonally across the slope. In fact the slope of the borders may be reduced to any extent necessary. Extreme conditions lead to the contour border system described on page 21. Some odd-shaped or off-size strips will generally be required, and these will be readily irrigated if they are not too different from the standard size and shape. Each strip must be level across but does not have to be at the same level as adjoining strips. After the strips have been adjusted to the topography on the map, they are staked out in the field.

The field to be prepared for border irrigation is first plowed or disked. In case the soil is too dry and hard to allow this to be done successfully, it is watered as well as its nature will permit. Occasionally the ground is first leveled in a rough way by teams or tractors and afterwards divided into strips. The location of the border levees is indicated by long stakes, which may be made of half laths; when these are set, a straight plow furrow is run between stakes to mark in a more definite way the location of each border. A foundation for the border may be made by plowing two or three furrows on each side of the staked line and throwing the dirt toward the center.

From this stage on two methods may be used to level the strips and form the levees. In one the earth is taken from both sides and in the other it is taken only from the high side of the levee. In the first

method scrapers either of the Fresno or the wheeled-Fresno type are used. These are driven back and forth at right angles to the levee lines, the dirt being scraped from the higher spots in the strips and dumped on the levees. The amount of earth dumped on each levee

FIGURE 11.—Preparing land for the border method of irrigation near Twin Falls, Idaho.

depends on how far the scraper loads are overlapped. If large levees are required, two or more scraperfuls of earth may be dumped in the same place, but in small low borders, a slight overlapping of the loads may suffice.

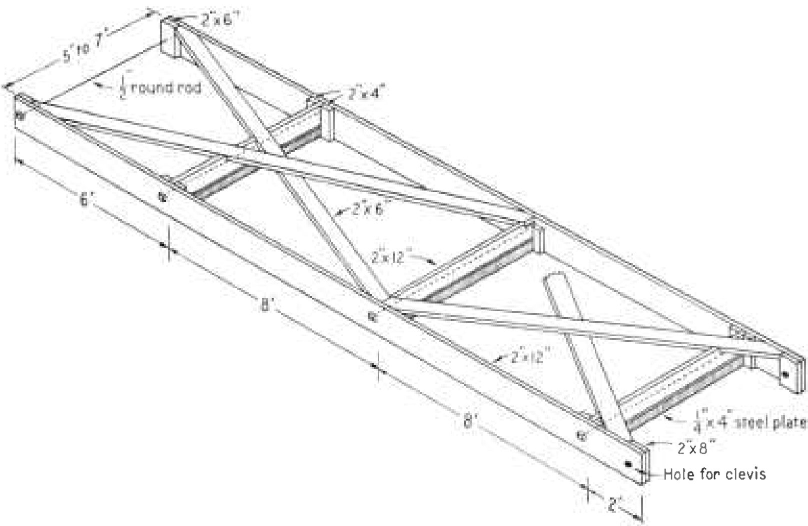

FIGURE 12.—Rectangular float or drag.

On the less permeable soils, where the irrigation stream required is small as compared with the width of strip, levees should be about 5 feet wide at the bottom and about 6 inches high after they have settled. Where larger streams are used the levees should be 6 or 8

feet wide at the base and 10 or 12 inches high. The levees are made broad and flat in order that farm machinery may readily cross them and so they will not be destroyed by stock when the fields are pastured.

The border levees, when first made, are composed of loose earth and are irregular in shape. To remedy the irregularity, several implements have been devised. One of these (fig. 11) is a wooden drag wider in front than behind. A common two-section drag harrow may also be used to advantage. A hinge should be placed in the middle of the evener bar to allow the harrow to lap down over the sides of the levee as it is drawn lengthwise of the border. A special machine called a border disk commonly is used for this purpose in the Salt River Valley, Ariz.

After the levees are built the space between each pair is carefully leveled and graded by an implement similar to the one represented

FIGURE 13.—Road grader used in preparing land for border irrigation.

in figure 12. The standard requirement of this part of the work is that the surface be practically level crosswise between levees, the greatest variation in elevation permissible being about one-tenth of a foot. Such close grading is necessary in order that water may flow down the strip in a thin sheet of uniform depth; otherwise the higher spots may remain dry or nearly so.

The loose earth placed in the low spots will settle the first time the strip is saturated. It is customary to add about 10 percent to the depth of fills to make up for settling. Thus if a smooth grade calls for a fill of 1 foot at a certain point, 1.1 feet of soil should be placed there when the land is first leveled. If possible, a trial irrigation should be made after the first leveling and before planting. This will serve to settle the fills and to show how well the land has been prepared. Generally it will be found necessary to cut down some high spots and fill up low spots.

If the strips are narrow and the levees are not to be too large, a second method may be used. Levees may be formed by moving the dirt from the high side of the strip, with a road grader or a V drag. When a road grader (fig. 13) is used the method most commonly followed is first to throw up two back furrows with an ordinary plow to mark the location of each levee. The grader then makes one

trip around the back furrows, throwing additional earth on the levee thus formed. Then the grader is shifted to the center of the border strip and with each round crowds the surface earth toward the partly formed levees. The cutter should be set at an angle of about 45°. So set, ordinary graders cover a width of about 6 feet.

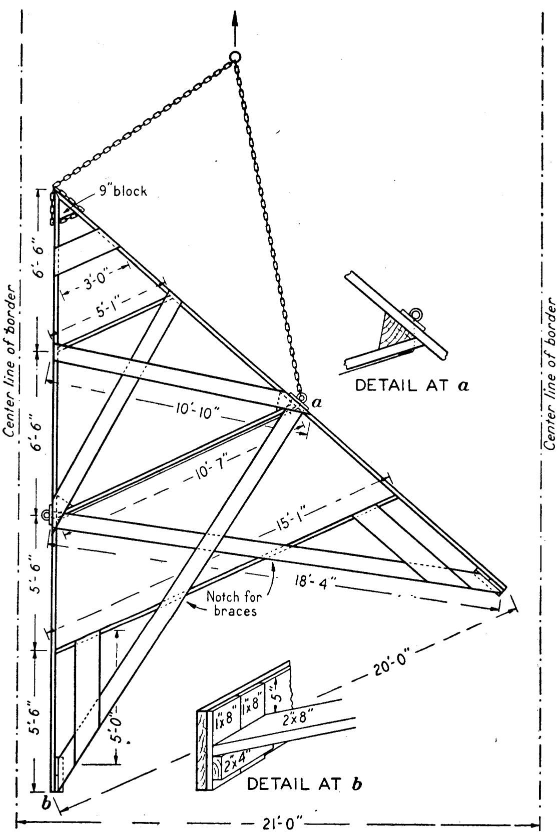

FIGURE 14.—Strip-border drag.

In the Willamette Valley, Oreg., the V-drag shown in figure 14[2] is much used. The chain hitch on this drag is so arranged that it can be made to throw all of the soil to either levee or to divide it more or less equally between the levees on each side of the strip. If one side of the strip is higher than the other, the drag is set to move the dirt from the high side toward the lower side, thus leveling the strip. Figure 15 shows one of these drags in operation.

Less attention need be paid to grade in the direction of the border. It is desirable to make the upper end of the strip level—that is, without grade—for a distance from the intake nearly equal to the width of the border strip. This causes the water, when first admitted through the border gate, to spread out sidewise and submerge all the space between the levees before it begins to flow down the slope. The slope from this point to the end of the strip may or may not be uniform. Making a slope uniform often necessitates the removal of much surface earth over considerable distances, which increases the cost of building borders and decreases yields on the scraped parts.

What grades are best for borders may be better understood by referring to the profiles in figure 16, which indicate in each case the original surface of the ground before any grading or leveling is done and the grade of the completed strip. In the upper profile the natural slope of the ground does not vary much, and accordingly the grade of the border is made uniform throughout, with the exception of the level part near the intake. In the next profile the surface is more uneven, calling for considerable cutting down of high spots and filling of low

[2] The V-drag shown in figure 14 was designed by A. S. King, of Oregon State Agricultural College.

ones. A uniform grade is not possible here without heavy grading, and to avoid this and to cut cost the grade is made to conform to the natural surface, which has its greatest fall in the lower half. In the third profile the slope is greater near the upper end of the strip.

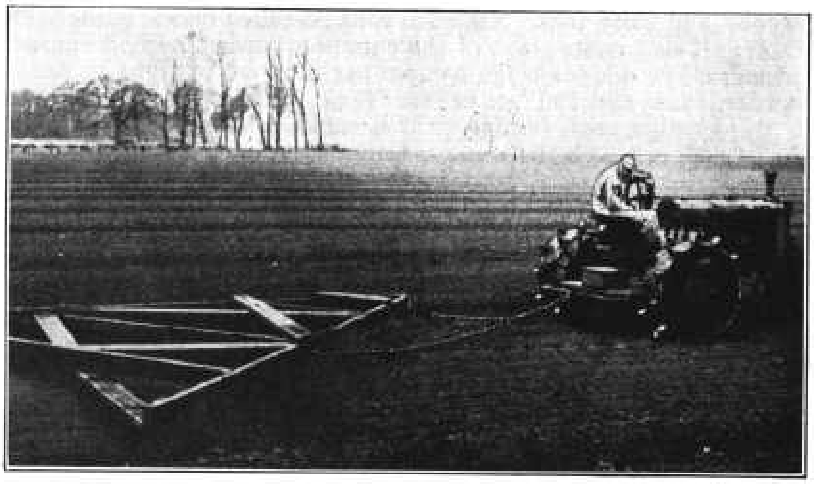

FIGURE 15.—Strip-border drag in use. (Picture by Oregon Agricultural Extension Service.)

SPECIAL WAYS OF PREPARING THE LAND

When the land to be irrigated is irregular, because of sand dunes or what are locally termed "buffalo wallows" or "hog wallows", a large steel leveler or scraper drawn by a tractor is frequently employed

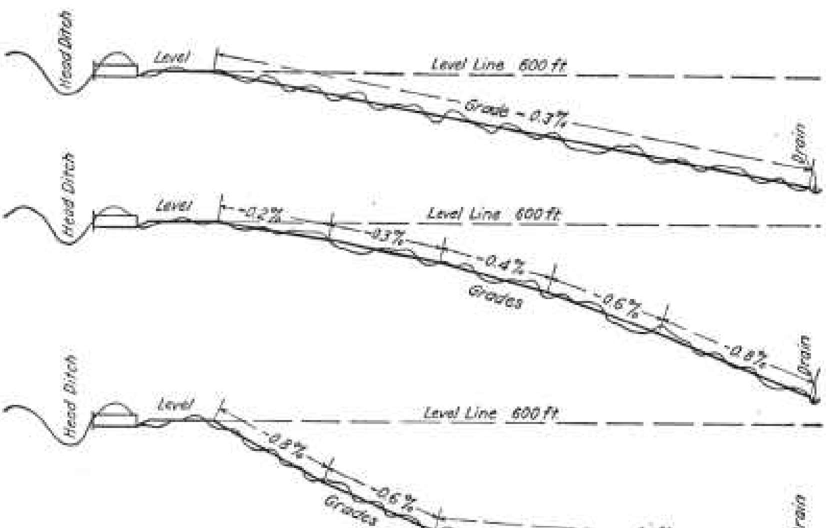

FIGURE 16.—Profiles of typical border strips showing surface before and after grading.

to do the rough grading. Figure 17 shows one of these outfits. Air is compressed by the tractor and conveyed through a pipe and hose to an air tank attached to the leveler in the rear. By means of the compressed air, the leveler is readily forced into hard, unplowed soil.

In compact soils it is sometimes difficult to get water down to the lowest roots. Often water applied to such soils in the usual way goes down no more than 6 inches. A small stream running for a long time over tight soils increases the penetration. There are types of soil, however, to which this method will not supply sufficient moisture to the second and third foot. On such soils so-called check borders are desirable. This modification of the common border method consists in forming a low dike or ridge by two backfurrows at right angles to the border levees and 100 feet or more apart, depending on the grade. With this change, each border strip becomes a series of rectangular checks in each of which the water is impounded until the soil has been

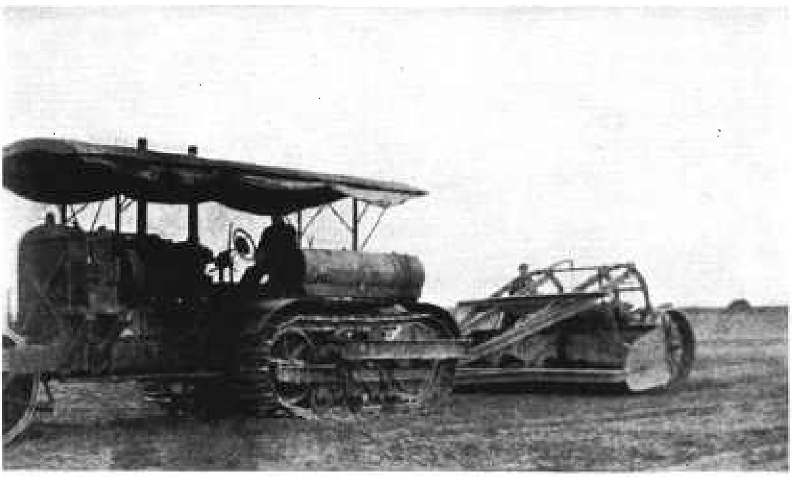

FIGURE 17.—A track-laying tractor drawing a land leveler.

moistened to the required depth. By placing a piece of canvas over a low part of these cross dikes the water may be held in each check for a considerable time. If water is held too long on any section when the temperature of the air and water is high the crop may be scalded.

APPLYING THE WATER

Irrigation of land properly prepared for the border method and with adequate ditches and structures is a simple process and is economical of labor and water. On the other hand, the process may be difficult and wasteful if the strips are poorly prepared or the ditches and structures are too small or out of repair.

DIVERSION OF WATER

In some areas neither border gates nor permanent check gates are used. The absence of permanent structures makes it easy to change the arrangement of supply ditches and strips, facilitates cleaning the ditches by machines, and reduces the cost of structures. Border gates also interfere to some extent with machine cleaning of supply ditches.

In most cases it is not good policy to build permanent structures before the first irrigation season as changes are often found to be necessary. If some type of border gate must be used, the single-wing gate shown in figure 4 is desirable because it is cheap and is easy to move.

Canvas dams are the most useful of the temporary devices. When used to control small streams of 5 cubic feet per second or less, the canvas dam consists of a strip of heavy duck 6 or 8 feet long by 5 or 6 feet wide, fastened along one longer edge to a pole or scantling. The pole is thrown across the ditch and the canvas pressed into the bank and sides of the ditch and a little loose soil thrown on it. When the stream must be divided between two or more strips and it is necessary to check the water between the strips, a hole can be cut in the upper part of the canvas or a curved pole can be used and part of the water allowed to flow over the dam.

To handle streams of 6 to 10 cubic feet per second requires a tarpaulin about 7 by 14 feet with a lumber framework. Such a frame is

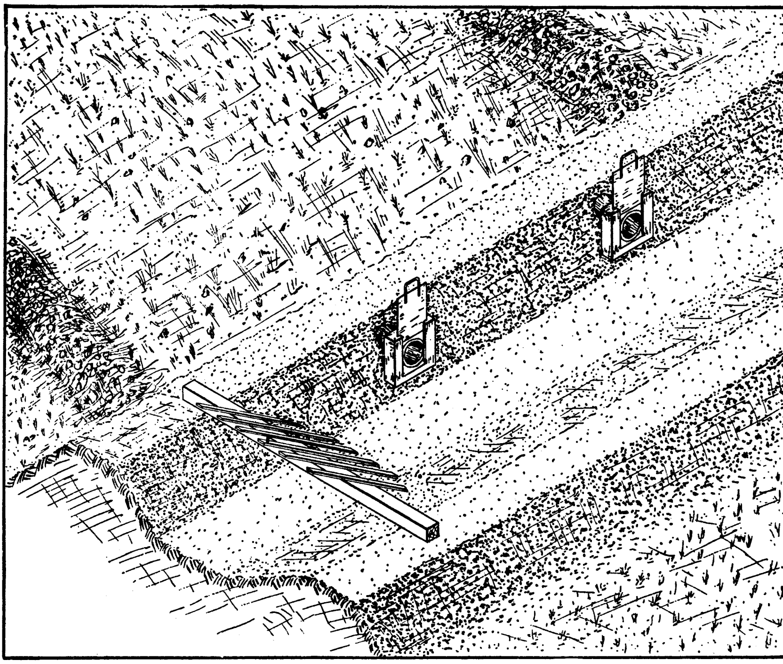

FIGURE 18.—An Arizona head ditch with two border gates and frame for canvas dam.

shown in figure 18. A round pole or sawed joist is placed across the ditch with the ends resting on the banks. Lighter pieces are slanted against the cross bar on the upstream side with the lower ends in the ditch. The cross bar is left in place when not in use, and the smaller sticks are placed on the bank. Movable metal dams, or tappoons, may be used in small ditches. They are made of a piece of galvanized sheet metal reinforced across the top with an angle iron and sometimes stiffened with vertical angle irons. These dams are driven into the bottom and sides of the ditch.

Where neither check nor border gates are used, the water is first allowed to fill the entire ditch and one or more openings are then made in the bank near the lower end, the number depending on how many strips can be irrigated at a time. When this first irrigation is completed, one or more openings are made upstream for the next strip or two, or whatever the number may be, and a canvas dam is

set in the ditch just below the lowest of the new openings. When in turn, the irrigating of this section has been accomplished, a third section is opened up, and a second canvas dam is set in place. Thereafter the two dams are alternated up the ditch. The advantage of this method, where no border gates are used, is that the openings in the ditch bank do not have to be closed while water is flowing. All openings, except the lowermost set, are closed at any convenient time before starting the next irrigation.

Where border gates but no check gates are in use the same plan is used, except that it is best to start irrigation at the upper end of the ditch. When that is done the canvas dams are easily placed in the dry ditch each time.

Where there are permanent checks and border gates labor is much reduced, and one man can handle larger streams.

EFFICIENCY OF IRRIGATION

If border strips have been properly prepared and the right size of stream is being used, the water will spread evenly over the width of the strip and advance uniformly down the slope. This ideal condition is not often attained, and it is usually necessary for the irrigator to guide the water away from low spots and to cover the higher spots. It will be found much easier to lead water by means of small ditches or embankments extending diagonally down the slope than to attempt to force it to cover high spots by shovelling up small cross dikes at right angles to the border levees.

By digging 3 or 4 feet to the lower part of the root zone with a soil auger or a shovel the irrigator can tell whether the water has gone down as far as that. If the lower part of the root zone is dry, means should be found, if possible, to hold water on the surface longer. Such tests should be made near the lower end of the strips, on the higher spots, and wherever the water remains on the surface less than the average time.

A check on the danger of overirrigation may be made by estimating the average application to the land covered as described below.[4]

A stream of 1 cubic foot per second will cover an acre to a depth of 1 inch in an hour. Therefore multiplying the number of cubic feet per second used by the number of hours required to irrigate an area and dividing by the number of acres irrigated will give the average application in inches. For instance, if a stream of 3 cubic feet per second is used for 30 minutes (0.5 hour) on a strip 33 by 330 feet (2 by 20 rods or 0.25 acre) 3 multiplied by 0.5 and divided by 0.25, or 6 inches of water is applied.

If the soil is found to be well-moistened to the full depth of crop roots at all points and the average depth of water applied is not much more than the soil will hold as useful moisture, the irrigation has been efficient. If, in the above example, the soil has a high water-holding capacity of 1.5 or 2 inches per foot depth and the third foot is found to be moist in all parts of the strip, little or no water has been wasted. It can be expected that the average quantity of water applied will be somewhat greater than the amount required to fill the soil to capacity. Except under conditions requiring unusual economy of water, all parts of the field should be thoroughly moistened. A perfectly uniform application is impossible. Therefore parts of the field will

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[4] See Farmers' Bulletin No. 1683, Measuring Water in Irrigation Channels.

ordinarily receive an excess, and the average will be slightly high. The average application should not exceed the requirement by more than 30 percent except under particularly adverse conditions.

Another check on the danger of overirrigation of the upper end of the strips may be made by watching the rate at which the water advances down the strip. So long as the water advances at a uniform rate, the loss of water by deep percolation in permeable soils is not great. On the other hand, when the runs are too long, the time required to irrigate the lower parts of the strips is much increased, causing a corresponding increase in the deep percolation loss. The remedy lies in the use of shorter runs and larger heads.

Some deep percolation is desirable and, in fact, essential to permanent farming. All natural waters contain dissolved minerals. Only a part of these minerals is used by plants. If there is no downward movement of water to the ground water these minerals will accumulate in the soil and eventually become so concentrated that crops will not grow. In many irrigated areas the rainfall during some season of the year is great enough to fill the soil to field capacity and permit some percolation to the water table. In other sections excess irrigation water is unavoidably applied. In all these areas there is no danger of destruction of farm lands by the accumulation of excess salts except where the water table is close to the surface. In still other places the water supply is so pure that the accumulation of harmful salts is extremely slow. There are areas, however, without these safety factors. In such places irrigators should use 10 or 20 percent more water than will be used by the crops and evaporated from the soil.

CONTOUR BORDERS

The border method is sometimes modified so that the water, instead of running down the steepest slope, runs more or less along the contours. The levees of the so-called contour borders are staked out on the regular grade considered most suitable. On permeable soils the strips should have a fall of 3 to 6 inches in 100 feet, while on less permeable soils the fall should be between 1 and 3 inches.

The strips are carefully leveled just as in the more usual system. The fact that the levees follow a winding course makes the width of contour strips uneven. They should be of about the same dimensions as the ordinary strips. The difference in elevation between adjoining strips and the width of strips are fixed one by the other on any particular piece of land. Sometimes contour strips must be narrower than the size of irrigation stream and permeability of the soil would require because if they are made wider too much earth would have to be moved in leveling. Deep cutting is detrimental to crop growth on some soils, and the cost of moving earth is always an important factor.

Where the contour border method is used the ditches must run down the steepest slope and more checks and drops are required. Otherwise the structures and method of applying water are the same as in the usual border method.

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